

ELECTRIC PROPULSION TECHNOLOGY APPLICATIONS

NAG3-1506

FINAL REPORT

INTRODUCTION:

CSTAR and NASA Lewis Research Center, having a mutual interest in the commercialization of electric propulsion (EP) technology, undertook this research project to identify and develop industrial applications of EP Technology. Developing terrestrial applications for technology developed for space applications is an ideal goal, in that such applications, if successful can be synergistic. The first area selected for investigation is the applications of ion thruster technology for etching and deposition.

WORK TO BE ACCOMPLISHED:

CSTAR, in the short period of the investigation, initiated several tasks including evaluation of technology transfer requirements, performing a literature survey and contacting industry regarding possible EP industrial applications, and initiating a parametric study of ion source design for industrial applications. The objective was to determine the ion source design and operating parameters that affect beam flatness. A small scale experiment, based on these results, would then be developed, fabricated and operated to verify and clarify the results from the theoretical model. Later work - if the results of the basic research indicate, and funding is approved - will develop a full scale experiment. This work will be performed in close coordination with NASA Lewis, as well as, with potential industrial users. The work tasks follow:

Task 1. Evaluation of Technology Transfer Requirements:

Perform a literature search and contact industry to determine and compare the devices and techniques that are currently available and used by industry. This will include specifying the requirements industry would impose on such a device if it were used as a manufacturing tool.

Task 2. Preliminary Investigations:

Perform preliminary math model calculations to determine the key parameters for controlling the flatness parameter (e.g., discharge chamber plasma density profile, grid geometry, hole alignment, etc.).

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Task 3. Parametric Study:

Based on the outcome of Task 2, perform a parametric study using the CSTAR PIC code

WORK ACCOMPLISHED:

CSTAR initiated an assessment of the devices and techniques currently available and utilized in industry for plasma processing, related to electric propulsion technologies. This research is to be continued during Phase II of this project. However, this initial assessment developed the following approach to facilitate the transfer of electric propulsion technologies for use in industrial applications.

Approach:

This approach requires a coordinated and managed application of research, surveys, and development of contacts as knowledge network is developed. In particular CSTAR would:

- a. Develop an industry contact list and classify according to technology needs or problem areas. Visit industry identified to have a potential application for EP technology. Face-to-face meetings are essential for developing relationships where tech transfer can occur.
- b. Develop and conduct a market survey. We have determined that a Market Survey is essential in establishing a viable technology transfer plan. The planning for the Market Survey is only in its embryo state.
- c. Continue the literature survey. We have determined that some work has been accomplished in this area; however, no-one has compiled the results in a compendium of capabilities, on-going research, and potential end users.

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d. Attend selected conferences, symposia, Manufacturing exhibits, and association meetings. The objective would be to enhance the literature survey and to simultaneously widen and strengthen the network.

e. CSTAR has already demonstrated that it has the expertise to transfer technology in a commercial fashion. The successes in the Laser Technology area are solid evidence that we can perform this successfully. Once we have identified an EP application that our survey indicates is marketable, we shall apply the same Technology Transfer principles exhibited in our Laser program.

Although the literature review and market surveys of the technology transfer approach are still in progress, two promising technology transfer opportunities have already been identified. Some of the papers accumulated during this review are listed in the bibliography. Because of time constraints, we were unable to review all the papers in depth.

Industrial Application of Ion Sources:

Our research to date has identified a specific requirement for industrial applications using ion sources. The requirement for most industrial applications is a broad-beam (45 to 60 cm), with a flat profile ($< 4\%$ max-min/max+min). CSTAR has developed a modeling code, called PIC, which was originally developed to model the ion dynamics through a single aperture of an ion thruster. This code was modified to enable the numerical modeling of multiple-aperture, broad-beamed, accelerator grids. It was planned to perform preliminary calculations to determine the parameters (e.g., discharge chamber plasma density profiles, grid geometry, aperture alignment, etc.) that control the ion beam profile. At the time the Grant ended, the modifications were completed and the code was being debugged. Because of the state of development, other than code comments, there is no documentation existing for the modified code.

Following the debug process and preliminary calculations, the next phase was to perform a parametric study to determine the set of parameters that result in the desired beam profile. A small scale experiment was to be designed to achieve the desired beam profile and to verify the theoretical model.

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Gas Leak Detection:

Another opportunity for technology transfer is in the commercial development of a gas leak detection system based on Raman scattering. A technique using laser induced spontaneous Raman scattering to accurately measure temperature and species concentrations in low thrust chemical rocket engines has been developed at the NASA-Lewis Research Center. With some modifications, this technique can be easily adapted to commercial applications for gas leak detection. The major advantage of this particular detection method is that the measurement itself is accomplished with a compact, lightweight optical head attached to flexible optical fibers. This allows the measurements to be made over a large area quickly in hostile and inaccessible environments with the data processing occurring in a safe and convenient location. Other advantages are that several gases can be detected at very low concentrations simultaneously, gases without an infrared spectrum (e.g., many diatomic gases) can be detected, in-situ, real-time measurements are possible, and gas temperatures over a wide range can be determined.

Commercialization of Technology:

Discussions with Rocketdyne Division, Rockwell International have commenced to develop an agreement for developing commercial applications of Thermal Spray Technology. The participants at Rocketdyne are: L. A. Flanigan, T.N. McKechnie, and P.D. Krotz; the CSTAR participants are: G. Garrison, J.B. Bible, and C.M. Sharp.

There are a number of Commercialization approaches being discussed: Teaming Agreement, Lead/sub-contract, team under a Grant, and Joint venture, are the options presently being explored. Each of these has its advantages and disadvantages. However, the teaming agreement seems to have advantage over the others. Under a teaming agreement, the lead is left open until the specifics are known, then as appropriate, one or the other party takes the lead.

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The Goals set for this venture are outlined below:

1. Commercialization of Aerospace Thermal Spray Technology Developed by Rocketdyne in Conjunction with NASA-MSFC. It is tentatively agreed that the technology be Jointly Marketed.

2. Identify Commercial industry problems that might be solved by applying the thermal spray technology. Ultimately the goal is to transfer this technology to industry.

3. Develop a thermal spray research/manufacturing center to spin-off the technology to commercial industries, as well as to DOD, DOE, NASA, and others.

The areas where thermal spray technology might be applied are:

1. Texturing of medical implants or other medical applications
2. Coating of sleeve bearings, valves, heat exchanges
3. Insulation of non-metal piping (foam, plastic, etc.)
4. Free-forming of refractory materials (crucibles, nose cones, etc.)
5. Replacing plating (hard chrome, etc, eliminates hazardous materials)
6. Ceramic to metal joining
7. Generation of new materials (graded, layered, composites, etc.)

This array of applications has potential benefits in the medical, environmental , automotive, electronic, and agricultural industries to name but a few.

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CONCLUSIONS:

An approach to effect the transfer of electric propulsion technologies for use in industrial applications has been developed. A literature review to identify potential technology transfer opportunities has been initiated. Two possible opportunities, the development of an ion source for materials processing and the commercial development of a gas leak detection system, have been identified and were being pursued when the decision was made to not fund Phase 2.

Future work was to include completing the literature review and performing market surveys., establishing contacts with industry, and developing several technology transfer projects with individual companies.

It is unfortunate that this project ended abruptly in its formative stage. Our initial investigations indicate that there are a multitude of industrial applications that could be developed and commercialized. Such transferred technology could provide a financially self sufficient commercial application(s). The procedure outlined above is in its essence that used, by CSTAR, to effect technology transfer in other areas.

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